CALIBRATION AND MAINTENANCE OF INSTRUMENTS FOR THE METEOROLOGY MONITORING PROJECT

Purpose

This Air Quality Group procedure describes:
- maintenance and calibration procedures for instruments used in the Meteorology Monitoring Project to measure atmospheric variables,
- the data acquisition systems for these measurements, and
- the equipment necessary to calibrate and maintain these meteorological instruments and systems.

Scope

This procedure applies to the calibration and maintenance of instruments used in the Meteorology Monitoring Project.

Hazard Control Plan

The hazard evaluation associated with this work is documented in Attachment 1: Initial risk = **low**. Residual risk = **low**. Work permits required: **none**. First authorization review date is one year from group leader signature below; subsequent authorizations are on file in group office.

Signatures

Prepared by: Bill Olsen, ESH-17	Date: 11/30/00
Approved by: George Fenton, Acting Meteorology Monitoring Project Leader	Date: 11/30/00
Approved by: Terry Morgan, Quality Assurance Officer	Date: 11/30/00
Work authorized by: Doug Stavert, ESH-17 Group Leader	Date: 11/30/00

1/25/01

CONTROLLED DOCUMENT

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In this document

This document addresses the following major topics:

1.0 General Information

Attachments

This procedure has the following attachments:

Attachment Number	Attachment Title	No. of pages
1	Hazard Control Plan	3
2	CMF1, Instruments for Measuring Wind Variables	1
3	CMF2, Instruments for Measuring Wind Variables	1
4	CMF3, Instruments for Measuring Atmospheric State Variables	1
5	CMF4, Temperature Probe Calibration	2
6	CMF5, Instruments for Measuring Precipitation-Related Variables	1
7	CMF6, Instruments for Measuring Radiative Flux Variables	1
8	CMF7, Instruments for Measuring Subsurface Variables	1
9	CMF8, Data Acquisition System	1
10	CMF9, Sodar	1

History of revision

This table lists the revision history and effective dates of this procedure.

Revision	Effective Date	Description Of Changes
0	3/30/95	New document.
1	7/10/96	Revisions.
2	2/11/98	Technical revisions and management changes.
3	8/30/99	Technical revisions, HCP added as attachment 1.
4	12/5/00	Added chapter on use of rain gauge with antifreeze system.

Who requires training ?

The following personnel require training before implementing these procedures:

- meteorological instrument technician

Training method

The training method for these procedures will be **on-the-job** training by a previously-trained individual (or the procedure author) and reading manufacturers' specifications and recommendations. Training is documented in accordance with the procedure for training (ESH-17-024).

General Information, continued

Prerequisites

In addition to training to this procedure, the following training is also required prior to performing this procedure:

- Ladder Safety, course number 12985

Definitions specific to this procedure

Sensor: The sensing element of an instrument that reacts to changes in the environment.

Transducer: That portion of an instrument that converts energy generated, through sensing, from one form to another.

Instrument: A measuring device consisting of a sensor and a transducer.

CMF: Calibration and Maintenance Form. Calibration and maintenance are closely related in this program and are recorded on combined forms for each instrument category. Maintenance work is recorded in the comments section of these forms.

References

The following are referenced in this document or are important references:

- ESH-17-011, "Logbook Use and Control"
- ESH-17-024, "Personnel Training"
- Complete manufacturers' specifications, literature, and instrument manuals are filed by the meteorological instrumentation technician. Only instrument specifications relevant to the calibration procedures and brief instrument descriptions are contained within this document.
- LANL Environmental Monitoring Plan (meteorology section)
- ESH-17-MET, "Quality Assurance Project Plan for the Meteorology Monitoring Project"

Note

Actions specified within this procedure, unless preceded with "should" or "may," are to be considered mandatory guidance (i.e., "shall").

2.0 Instruments for Measuring Wind Variables

2.1 Propeller vane anemometer

Instrument description

The propeller vane (propvane) model 35005 is manufactured by the RM Young Co. The wind speed sensor is a four-blade helicoid propeller and has a 30-cm pitch. The propeller diameter is 22 cm for polystyrene propellers and 18 cm for polypropylene propellers. The wind direction sensor is a 23-cm square fin mounted on a 52-cm-long horizontal shaft as measured from the instrument pivot axis to the center of the fin. The polystyrene and aluminum wind direction sensors have the same damping ratio, which is h=0.49, and the same damped natural wavelength, which is 7.2 m.

The wind speed transducer is a dc tachometer to which the propeller is coupled. The wind direction transducer is a precision potentiometer that is coupled to the vane axis shaft via gears.

For propvanes installed on tower levels 1 (11.5 m), the propeller and vane are polystyrene to improve the sensor response. Tower levels 2 and above are polypropylene propellers and aluminum vanes.

Specifications

The instrument specifications are as follows

Wind Speed
- Range: 0 to 50 m/s
- Sensitivity: 8.8 m/s = 1800 rpm = 2400 mV
- Accuracy: ± 0.04 m/s (± 12 mV)

Wind Direction
- Range: 1° to 355°
- Sensitivity: 28 ohms/degree
- Accuracy: ± 3.0° (angle) from 10° to 350°

Speed Parameter	Polystyrene Propeller	Polypropylene Propeller
threshold	0.1 to 0.2 m/s	0.2 to 0.4 m/s
distance-constant	1.0 m	3.3 m

Common problems

The most common problem with the propvane instrument is partial or complete bearing failure. A partial bearing failure means increased friction, which results in reduced signal output for wind speed or a sluggish azimuth response.

The anemometer propellers and vanes at tower level 1 are susceptible to hail damage and to damage from falling clumps of snow which accumulate on the tower during winter storms.

2.1 Propeller vane anemometer, continued

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the propeller vane anemometer:

- RM Young model 1722 vane angle calibrator
- Voltage and resistance meter
- Precision voltage source
- “Bulls-eye” level
- RM Young model 18310 anemometer torque disk
- RM Young model 18330 vane bearing torque gauge
- RM Young model 18801 rotational calibration unit
- Calibration and Maintenance Form 1 (CMF1)

Steps to calibrate

To calibrate propvanes, perform the following steps:

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1</td><td>Read all the manuals and manufacturers' literature on the propvane and calibration equipment before proceeding.</td></tr>
<tr><td>2</td><td>Install the propvane to be calibrated on the model 1722 vane angle calibrator with the propvane cover removed.</td></tr>
<tr><td>3</td><td>Place the bulls-eye level on the very top of the propvane and adjust for level by adjusting the leveling screws on the vane angle calibrator.</td></tr>
<tr><td>4</td><td>Using the model 18330 torque gauge, measure the wind vane system torque in four quadrants (room air must be still).</td></tr>
<tr><td>a.</td><td>Place the vane at approximately 90 degrees (as measured by the protractor) and measure the torque in both directions.</td></tr>
<tr><td>b.</td><td>Move the vane to 180 degrees and measure again.</td></tr>
<tr><td>c.</td><td>Move the vane to 270 degrees and measure again.</td></tr>
<tr><td>d.</td><td>Move the vane to 360 degrees and measure again.</td></tr>
<tr><td>e.</td><td>Record the instrument serial number and the torque value in the appropriate spaces on CMF1. If this torque value is greater than 20 g-cm, then the vertical shaft bearings must be replaced—see the instrument manual.</td></tr>
<tr><td>5</td><td>Conduct wind speed system torque test. Remove the propeller, and using the model 18310 torque disk, measure the wind speed system torque in four quadrants in the CCW direction. The torque test pass limit is ≤ 0.6 g-cm.
<table>
<tr><th>If the torque test result is…</th><th>then…</th></tr>
<tr><td>≤ 0.6 g-cm</td><td>record a check mark in the torque test column of the CMF1.</td></tr>
<tr><td>> 0.6 g-cm</td><td>record the torque value in the torque test column of the CMF1.</td></tr>
</table></td></tr>
</table>

2.1 Propeller vane anemometer, continued

Step	Action
6	Conduct a spin-down bearing test. This test duplicates the effort in Step 5, but is not sensitive to imbalance, as is Step 5.
a.	With the torque disk still in place, couple an 1800-rpm spin motor to the shaft.
b.	Spin the assembly CCW to speed.
c.	Remove the spin motor, and on the CMF1, record the time required to spin down to a stop. Empirical work has shown that a >55-second spin down test indicates good bearings.
7	Measure the wind speed transducer output.
a.	Couple the model 18801 rotational calibration unit to the propvane.
b.	Connect the voltmeter to the terminal strip on the model 1722 vane angle calibrator between the “filtered wind speed” and “common” terminals.
c.	Run the 18801 unit at the three speeds (counterclockwise only) required on CMF1, and record on that form the tachometer response as measured by the voltmeter.
8	Measure the slip ring electrical contact resistance.
a.	Remove the 18801 unit and the tachometer housing from the propvane.
b.	Connect a shorting plug to the wire assembly connector that is exposed when the tachometer is removed.
c.	Connect the resistance meter to the “raw wind speed” and “common” terminals on the model 1722.
d.	Measure the resistance of this circuit while slowly rotating the propvane through 360 degrees.
e.	On the CMF1, record a visual indication of this average resistance and maximum variation. What is being measured in this step is the quality of the slip ring electrical contact of the propvane. The average resistance shall be less than 1.0 ohm, with a maximum variation of ±0.25 ohm.
9	Perform azimuth transducer measurements.
a.	Connect the precision voltage source to the “3550 millivolt (mV) excitation” and “common” terminals of the model 1722.
b.	Monitor the excitation voltage with the voltmeter and adjust the precision source to +3550 mV.
c.	Connect the voltmeter to the “azimuth” and “common” terminals of the 1722.
d.	Rotate the propvane to the five azimuth calibration points as measured by the model 1722’s protractor, first in a clockwise (cw) and then in a counterclockwise (ccw) direction.
e.	For each calibration point, use the voltmeter to measure the azimuth angle value and record this value on the CMF1. Indicate the ccw values with parentheses.

2.1 Propeller vane anemometer, continued

Step	Action
f.	Sweep the propvane slowly through 360 degrees while monitoring the azimuth angle, as measured by the voltmeter. The angle should increase slowly as the vane is moved. Jumps or other inconsistencies indicate that the azimuth potentiometer (pot.) has bad or worn spots. Remember that the azimuth pot. has a dead band from 355 to 360 degrees. **If the azimuth pot. is…** / **then…** good / record a (√) on the CMF1 not good / note the problem(s) on the CMF1
10	File the CMF1.
a.	Perform postcalibrations on all instruments removed from a tower. Completion of the previous steps, along with a filled out CMF1, constitute a postcalibration (postcal.) of an instrument removed from service (before refurbishment).
b.	Check the CMF1 postcal. box and date and sign the form at the top.
c.	Insert the completed CMF1 in the tower activity log notebook postcalibration section for the tower from which the propvane was removed.

2.1 Propeller vane anemometer, continued

Propvane maintenance

The purpose of propvane maintenance is to restore the instrument to "as new" condition. Where calibration step references say to "record failed test values," the technician must ensure that all tests are passed.

Steps to maintain propvanes

To maintain propvanes, perform the following steps:

Step	Action
1	Initiate a new CMF1 for this refurbished instrument(s).
2	Thoroughly clean the slip ring and brush assembly with contact cleaner (GC Electronics DE-OX-ID, catalog no. 10-1902) using a soft artist's brush. Sparingly apply anti-friction silicone grease (Dow Corning Molykote 44) to the slip ring assembly contact rings.
3	Repeat *calibration steps 2, 3, and 4.*
4	Repeat *calibration Step 8.*
5	Install new propvane tachometer and input shaft bearings.
6	Install a new azimuth potentiometer (pot.).
7	Install new vertical shaft bearings if they fail the <20 g-cm torque limit test, as qualified in *calibration Step 4.*
8	Repeat *calibration steps 5 through 7.*
9	Perform azimuth transducer calibration.
a.	Connect the voltmeter to the "azimuth" and "common" terminals of the 1722.
b.	Rotate the propvane to 180° azimuth as measured by the model 1722's protractor.
c.	Manually rotate the loosely mounted azimuth pot. until the voltmeter reads 1800 mV.
d.	Check the readings at 30°, 90°, 180°, 270°, and 330° as measured by the model 1722's protractor.
e.	Manually rotate the loosely mounted azimuth pot. to balance the measurement error at these five points, as read by the voltmeter. This position should be the optimum set point for the azimuth pot.
f.	Tighten the azimuth pot. in place with its mounting screws.
10	Repeat *calibration* Step 9.

Steps continued on next page.

2.1 Propeller vane anemometer, continued

Step	Action
11	Replace slip ring and brush assemblies if they are worn or damaged. This is a very sensitive replacement procedure with the following being only a cursory listing. A complete description would be too difficult -- the techniques must be observed.
a.	Disconnect the transducer wires that are connected to the terminal strip attached to the instrument base mounting plate.
b.	Remove the instrument base mounting plate.
c.	Remove the brush bracket with the attached brush assembly.
d.	Unsolder the wires which connect to the slip ring assembly.
e.	Remove the slip ring assembly by removing the screw that holds it to the vertical shaft.
f.	Install the new slip ring assembly by reversing the removal step. Use removable Loctite Threadlocker on the screw.
g.	Visually inspect the brush assembly. The contact fingers must be “perfectly” aligned in two planes and the fingers must be spaced to match the slip ring assembly.
h.	Measure the gap between the opposing fingers. This distance must be 0.31 in. to 0.32 in. If the gap is too narrow, there will be excessive slip ring wear and vane friction. If the gap is too wide, there will be an unreliable electrical contact for the wind speed signal.
i.	Mount the brush assembly on the brush bracket and install this assembly with the two mounting screws. Align the assembly so that the fingers are parallel to the upper plate of the instrument.
j.	Tighten the brush bracket screws and check the slip ring contact force of opposing fingers. If this contact force is not balanced, it will be necessary to slightly loosen the screws holding the brush bracket support to the upper plate of the instrument. Carefully adjust the brush bracket support so that the brush finger to slip ring contact force is balanced. Tighten the brush bracket support screws.
k.	Remove the two brush bracket screws, one at a time, and apply Loctite Threadlocker to the screws and replace them; assuring that the brush fingers are still aligned as in Step i.
l.	Replace the base mounting plate and use Loctite Threadlocker on the bolts.
m.	Reattach the transducer wires to the base mounting plate terminal strip.
n.	Repeat *maintenance* steps 2 through 4 and indicate in the comments section of CMF1 that the slip ring and brush assemblies have been replaced.
12	Balance the vane assembly.
a.	Remove the propvane from the model 1722.

Steps continued on next page.

2.1 Propeller vane anemometer, continued

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>b.</td><td>Hold the propvane horizontally (with a propeller installed) in a room with no air currents. There should not be any vane rotation from a horizontal vane position if the assembly is balanced.
<table>
<tr><th>If…</th><th>then…</th></tr>
<tr><td>balance adjustment is necessary, and the propeller is polypropylene and the vane is aluminum</td><td>(1) loosen the set screws of the steel ring mounted on the tachometer housing,
(2) slide this ring along the tachometer housing to achieve balance, and
(3) tighten the ring in place.</td></tr>
<tr><td>balance adjustment is necessary, and the propeller and vane are polystyrene</td><td>(1) remove end cap from the vane,
(2) insert (or remove) pieces of solder to achieve balance, and
(3) replace the vane end cap with silastic adhesive.</td></tr>
</table></td></tr>
<tr><td>13</td><td>The previous steps and the CMF1 filled out are a pre-calibration (check this box on CMF1) of an instrument(s) to be installed on a tower as part of the annual meteorological instrumentation calibration cycle. Insert the completed CMF1 in the appropriate tower activity log notebook section for the tower that this instrument(s) is intended. Sign and date the CMF1 at the top indicating the refurbishment date. When the instrument(s) is installed on a tower, enter the date, time, and signature.</td></tr>
<tr><td>14</td><td>Apply a good-quality automotive wax to the painted surfaces of the propvane and Armor All protectant to the propeller to minimize snow and ice accumulation and to protect these surfaces.</td></tr>
<tr><td>15</td><td>Conduct monthly (within the first week of each month) tower visits to inspect the instrumentation. Inspect and replace any broken vanes or propellers. Visually note propeller rotation and compare vane position and movement between tower levels. Perform these inspections within 3 days following a hailstorm or severe snowstorm.</td></tr>
</table>

2.2 Vertical wind anemometer

Instrument description

Measurement of the vertical component of the wind is done with the RM Young model 27106 anemometer. This anemometer is mounted vertically and the sensor is a 30-cm-pitch four-blade helicoid propeller. The propeller diameter is 22 cm for polystyrene propellers and 18 cm for polypropylene propellers.

The propeller responds only to that component of the wind that is parallel to its axis. Propeller response as a function of its orientation to the wind closely approximates the cosine law. When the wind is exactly perpendicular to the axis of the propeller (a horizontal wind), rotation stops. The output signal is positive (cw-updraft) or negative (ccw-downdraft), depending on the direction of the vertical wind component. Multiplying the signal by 1.25 to correct for most of the non-cosine response of the propeller obtains a better estimate of the vertical wind. With this correction, which is executed in the datalogger, good estimates are obtained for flow within ± 30 degrees from the horizontal, a condition satisfied most of the time.

The propellers are installed with propeller extensions to improve the response of the instrument at low wind speeds. The extension is three inches long and has the same diameter as the front section of the instrument to provide a physical configuration which is symmetrical on each side of the propeller.

The anemometer's transducer is a dc tachometer to which the propeller is coupled. For anemometers installed on tower levels 1 (11.5 m), the propeller is polystyrene to improve the sensor response. Tower levels 2 and above are polypropylene propellers.

Specifications

The anemometer specifications are as follows:

Range:	± 22 m/s
Sensitivity:	8.8 m/s = 1800 rpm = 500 mV
Accuracy:	± 0.04 m/s (± 2.5 mV)

Speed Parameter	Polystyrene Propeller	Polypropylene propeller
threshold	0.1 to 0.2 m/s	0.2 to 0.4 m/s
distance-constant	1.0 m	3.3 m

Common problems

The most common problem with this instrument is partial or complete bearing failure. A partial bearing failure means increased friction, which results in reduced signal output for vertical wind speed.

In winter, the anemometer propellers at tower level 1 are susceptible to hail damage and to damage from falling clumps of snow which accumulate on the tower during winter storms and hail storms.

2.2 Vertical wind anemometer, continued

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the vertical wind anemometer:

- Voltage and resistance meter
- RM Young model 18310 anemometer torque disk
- RM Young model 18801 rotational calibration unit
- 1800 rpm spin motor
- Calibration and Maintenance Form 2 (CMF2)

Steps to calibrate

To calibrate vertical anemometers, perform the following steps:

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1</td><td>Read all the manuals and manufacturers' literature on the instrument and calibration equipment before proceeding.</td></tr>
<tr><td>2</td><td>Conduct a wind speed system torque test.</td></tr>
<tr><td>a.</td><td>Remove the propeller, hold the instrument horizontal. Using the model 18310 torque disk, measure the wind speed torque in four quadrants in both directions at each point. The torque test limit is ≤ 0.5 g-cm.
<table>
<tr><th>If the test result is…</th><th>then…</th></tr>
<tr><td>≤ 0.5 g-cm</td><td>record a check mark in the torque test column on the CMF2.</td></tr>
<tr><td>> 0.5 g-cm</td><td>record the torque value in the torque test column on the CMF2.</td></tr>
</table></td></tr>
<tr><td>3</td><td>Conduct a spin-down bearing test. This test duplicates the effort in Step 2, but is not sensitive to imbalance, as is Step 2.</td></tr>
<tr><td>a.</td><td>With the torque disk still in place, couple an 1800-rpm spin motor to the shaft.</td></tr>
<tr><td>b.</td><td>Spin the assembly to speed.</td></tr>
<tr><td>c.</td><td>Remove the spin motor, and, on the CMF2, record the time required to spin down to a stop. Spin the instrument down in both directions. Empirical work has shown that a >55-second spin down test indicates good bearings.</td></tr>
<tr><td>4</td><td>Measure the wind speed transducer output.</td></tr>
<tr><td>a.</td><td>Couple the model 18801 rotational calibration unit to the anemometer.</td></tr>
<tr><td>b.</td><td>Connect the voltmeter to the instrument output pins (A & B).</td></tr>
<tr><td>c.</td><td>Run the 18801 unit at the three speeds (both ccw and cw) required on the CMF2. On that form, record the tachometer response as measured by the voltmeter. Pin A is positive for a ccw rotation.</td></tr>
</table>

Steps continued on next page.

2.2 Vertical wind anemometer, continued

Step	Action
5	File the CMF2.
a.	Perform postcalibrations on all instruments removed from a tower. Completion of the foregoing steps, along with a filled out CMF2, constitute a postcalibration of an instrument removed from service (before refurbishment).
b.	Check the CMF2 postcal. Box and sign and date the form at the top.
c.	Insert the completed CMF2 in the tower activity log notebook postcalibration section for the tower from which the anemometer was removed.

Maintenance steps

The intent of these maintenance steps is to restore the instrument to “as new” condition. Where calibration step references say to “record failed test values,” the technician must ensure that all tests are passed.

To maintain vertical anemometers, perform the following steps:

Step	Action
1	Initiate a new CMF2 for this refurbished instrument(s).
2	Install new anemometer tachometer and input shaft bearings.
3	Repeat *calibration* steps 2 through 4.
4	Insert the completed CMF1 in the appropriate tower activity log notebook section for the tower that this instrument(s) is intended. **Note**: The foregoing steps and the CMF1 filled out are a pre-calibration of an instrument(s) to be installed on a tower as part of the annual meteorological instrumentation calibration cycle.
5	Apply a good-quality automotive wax to the painted surfaces of the anemometer and Armor All protectant to the polypropylene propeller to minimize snow and ice accumulation and to protect these surfaces.

2.3 Sonic anemometer

Instrument description

The model SWS-211/3Sx sonic anemometer/thermometer (3-D sonic) is manufactured by Applied Technologies, Inc. The instrument consists of opposing pairs of sonic transducers precisely and rigidly positioned in three orthogonal axes. The 3-D sonic determines the wind velocity components along these three axes by measuring the transit time of sonic pulses transmitted between the opposing transducers. The air temperature is measured by the sonic transit time in the vertical or “w” path and is corrected for vertical wind contamination. Obviously, the 3-D sonic is dependent upon careful calibration, which requires entry of temperature and humidity data and zero wind conditions.

The 3-D sonic has a 10-Hz data rate for output of the three wind components (u, v & w) individually but is slowed to 5 Hz when the U & θ (resultant horizontal wind speed and direction) option is selected. The other outputs are vertical wind speed (w) and temperature (T). The opposing transducers are spaced approximately 15 cm apart.

Specifications

The instrument specifications are as follows:

	U	θ	w	T
Range:	0 to 20 m/s	0° to 360°	± 5 m/s	-50 to +50° C
Sensitivity:	62.5 mV/m/s	6.9 mV/degree	250 mV/m/s	25 mV/°C
Accuracy:	± 0.05 m/s	± 0.1°	± 0.05 m/s	± 1° C

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the sonic anemometer:

- Applied Technologies' zero air tube.
- Electronic thermometer to measure temperature within the zero air tube.
- Relative humidity data at the time of the calibration.
- Estimated average relative humidity for the measurement period.
- Computer with RS-232 com. port and data retrieval software such as VersaTerm (VTERM). Or, a Campbell Scientific datalogger set up to accept the 3-D sonic output.
- Calibration and Maintenance Form 2 (CMF2)

2.3 Sonic anemometer, continued

Maintenance and calibration

The instrument maintenance and calibration is well documented in the equipment manual. Follow the manufacturer's procedure for performing maintenance and calibration. Fill out a CMF2 as required and insert this form in the appropriate section of the tower activity log notebook.

On the CMF2 form, record the variables: temperature, vertical wind speed, and horizontal wind speed and direction for the sonic and the level 1 conventional instruments. The measurements must be for corresponding 15 minute data periods. Compare the measurements for an indication of the proper operation of the sonic anemometer.

2.4 Sodar

Instrument description

The model 2000 Doppler acoustic sounder, or sodar (sound detection and ranging) is manufactured by AeroVironment (A-V). It measures winds up to 781 m AGL (above ground level) by transmitting sound pulses and measuring the wind induced Doppler shift of the returned sound energy. It provides measurements of horizontal wind speed and direction, vertical speed, and standard deviations at 32 m intervals from 65 to 781 m AGL.

The sodar is permanently installed at the TA-6 met. tower site. The system consists of the central control and processing electronics package (sodar controller), three large transmitting antennas and enclosures, acoustic barriers for the antennas, and an RM Young model 27004 uvw anemometer which provides a measurement of 10 m AGL wind speed that is part of the Sodar output data set. There is a terminal/printer at the site for diagnostic work and a computer which provides the prime data collection.

The sodar's three antennas are operated sequentially to measure orthogonal components of the wind. An antenna first transmits an acoustic pulse and then switches to a listen mode to receive the returned energy. The sodar's two horizontal antennas, which are tilted at a 20° zenith angle with one pointed north and the other pointed east, provide two vector components, which are combined to produce a resultant wind speed and direction. The third antenna points straight up and provides a measure of the vertical component of the wind.

Specifications

The sodar's specifications, as advertised by A-V, are as follows:

Range (height):	60 to 1500 m
Range (horizontal speed):	0 to 35 m/s
Range (vertical speed):	± 3.7 m/s
Range (wind direction):	0 to 359 degrees
Accuracy (horizontal):	± 0.2 m/s
Accuracy (vertical):	± 0.1 m/s
Accuracy (wind direction):	± 5 degrees

2.4 Sodar, continued

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the sodar:

- A-V responders (300-m and 600-m)
- Carpenter's level and inclinometer
- The on-site Texas Instruments (TI) printer/terminal.
- Tektronix model 2236A oscilloscope (scope).
- Hand tools.
- Voltage and resistance meter.
- Calibration and Maintenance Form 9 (CMF9)
- Counter/timer

Steps to calibrate

To calibrate the A-V model 2000 sodar, perform the following steps:

Step	Action
1	Read all manuals and manufacturers' literature on the sodar and calibration equipment before proceeding.
2	Reduce the sodar controller output volume control to allow safe access to the antennas.
3	Remove the antenna access covers.
4	Check the 20° tilt of the horizontal antennas by placing the inclinometer on the antenna transducer. The tilt shall be 20° ± 1.0° . Record measurements on CMF9.
5	With the inclinometer, check the level of the vertical antenna's transducer. It shall be level to ± 1.0°. Record measurements on CMF9.
6	Replace the antenna covers, but use only a few fasteners, because it will be necessary to access the antennas as testing proceeds.
7	Return the sodar controller to full output volume and turn up the monitor speaker volume control to a comfortable listening level.
8	Disconnect the computers from the sodar controller and connect the TI terminal.
9	Use the counter/timer and Tektronix oscilloscope to check the Sodar's local oscillator. Allow a minimum 30 minute warm up of these instruments before making any measurements. The test point is near the exposed edge of the A2 card and can be accessed with any suitable probe. The frequency is 1747 ± 0.1 Hz and the amplitude should be a nominal 20 volts peak to peak (p-p). Refer to the A2 board schematic for adjustments.
10	Run the system diagnostics per the sodar manual, appendix D. Record pass/fail on CMF9.

Steps continued on next page.

2.4 Sodar, continued

Step	Action
11	When the diagnostics are successfully completed, remain in the diagnostic routine and conduct a system noise test (a. through f.). Record antenna tests and comments on CMF9.
a.	In the diagnostic “manual transmit and display” mode, fire the antennas individually and observe the response on the scope.
b.	After an antenna has been fired, the initial scope display will be a normal return. After the return energy is dissipated, the antenna will remain in its “listen” mode.
c.	Watch the scope during this period and listen to the monitor speaker. For the most part, on a calm day with no obvious audible noises, the scope trace is a straight line and the monitor speaker quiet. Stay in this mode for a while and try to identify any noises which might disturb this condition, such as birds, a wind gust, etc.
d.	Repeat this test for each antenna.
e.	If an input filter is bad (or going bad) it will “pop up” continuously (or occasionally) without any obvious noise to cause the response.
f.	Exit the diagnostic test routine.

Steps continued on next page.

2.4 Sodar, continued

Step	Action
12	Conduct responder checks of the system by performing steps a. through f. The responders have two operating modes: “T” provides a continuous tone -- which the sodar will interpret as +5.0 m/s for the 300-m and -5.0 m/s for the 600-m responders from 60 to 750 m AGL. “R” provides a pulse which is delayed to look like a 300-m or 600-m AGL return (depending upon which responder is used). The tonal burst frequency which forms this pulse is such that the sodar will interpret it as +5.0 m/s for the 300-m and -5.0 m/s for the 600-m responders at the particular height. The Sodar collects and processes data based on the original design, which had the horizontal antennas tilted to a 30 degree zenith angle -- this has not been changed although the angle is now 20 degrees. All the data adjustments for the 20 degree zenith angle are done in the data collection programs. DOPLMAIN, the on-site computer program, does speed correction only and DATAMAN, the TA-59 program, does speed and height AGL corrections. For all work done with the TI terminal, there will be no correction for the 20 degree zenith angle. In both these situations, it should be noted that the responder frequency will be interpreted by the sodar as indicated above (+5.0 m/s or -5.0 m/s) if the sodar is in the “fixed” mode without any offset. If the sodar is in the “tracking” mode, then it will be necessary to determine the amount of the offset from the data header to determine whether the sodar is indeed operating correctly. Refer to the sodar manual for “fixed” vs “tracking” modes. Record responder test results on CMF9.
a.	Place one responder in one antenna and the other in another antenna. Replace the antenna access covers each time a responder is placed in an antenna.
b.	On the sodar front panel, set the data collection period from 15 minutes to 5 minutes. Press the “enter” button to effect this change.
c.	Turn down the transmit pulse amplitude with the power amplifier volume control until the transmit pulse just triggers the responders. The responders are evident in the scope display.
d.	At the end of each 5-minute data period, move the responders so that at the end of these tests, each antenna will have had each responder installed, thereby providing a 300-m “R” test, 600-m “R” test, and continuous tone “T” tests.

Steps continued on next page.

2.4 Sodar, continued

Step	Action
e.	To determine how the sodar interprets the 300-and 600-m "R" tests, examine the IN, IE, and IV columns (depending upon which antenna contains which responder) in the output data file. The responder height will be evident in that the intensity will be a large number when compared with numbers above and below in the column. In the vertical antenna, the responders will indicate a height greater than 300 and 600 m because the responders are designed for use in horizontal antennas, which are tilted at 30 degrees. Responders are designed to provide height AGL ...not the length of the beam path.
f.	When the responders are in the "T" mode then the sodar will show +5.0 m/s (300-m) and -5.0 m/s (600-m) from 65 to 781 m AGL as noted in the NS, EW, and V columns. The R (reliability) column for each wind component will be zero (highest reliability on a scale from 0 to 9) because the responder output power is uniform and relatively high.
13	The sodar 10-m uvw anemometer (see section 2.5) input channels shall be calibrated to ensure that the sodar is correctly receiving these signals. Perform steps a. through c. and record responses on CMF9.
a.	These signals are simulated at the uvw input connector with a precision voltage source. Check the sodar response at the end of a 5-minute data period by looking at the output data.
b.	Because the uvw anemometer wind signals are + and - voltages, simulate both polarities for each signal (u, v, and w).
c.	Refer to the adjustments described in the sodar manual.
14	If adjustments are made, rerun steps 13 a. through c. and record the responses on CMF9.
15	Reset the front panel switch to provide 15-minute data collection periods (normal operation). Press the "enter" button to load this period into the sodar.
16	Disconnect the TI terminal/printer from the sodar and reconnect the computer's cable. The sodar is now back to its normal operating configuration.
17	Insert the CMF9 in the appropriate section of the Sodar activity log notebook.

2.4 Sodar, continued

Maintenance steps

To maintain the A-V model 2000 sodar, perform the following steps:

Step	Action
1	The speaker diaphragms are the most frequent item to fail in the sodar. The diaphragms are replaced annually as preventive maintenance, but are checked weekly to detect failure. To perform the monitoring, simply listen to each antenna when it fires – a failed diaphragm is obvious.
2	The sodar antenna enclosures and the acoustic walls are covered with an acoustic foam material. This foam degrades slowly because of exposure to the elements. Visually check the foam acoustic material at the annual meteorological instrumentation calibration cycle.

2.5 uvw anemometer

Instrument description

The RM Young model 27004 uvw anemometer is mounted on the TA-6 meteorological tower at the 10-m level. The uvw anemometer signals are received by the sodar controller and processed along with the acoustically measured wind data. This 10-m anemometer is useful as a real-time quality control tool for the sodar. If the first acoustically measured wind data at 60 m does not conform to the uvw-measured wind data, then it is prudent to check the system.

The model 27004 uvw consists of three model 27106 sensors (RM Young vertical anemometers) mounted orthogonally on a special housing. The two horizontal arms provide the vector components of the horizontal wind, and the vertical arm provides the vertical component. The uvw resembles the sodar in that the wind is sensed as vector components.

Specifications

The instrument specifications are as follows:

Range:	± 30 m/s
Sensitivity:	8.8 m/s = 1800 rpm = 500 mV
Accuracy:	± 0.04 m/s (± 2.5 mV)

Polypropylene propeller:

Threshold: 0.2 to 0.4 m/s
Distance-constant: 3.3 m

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the uvw anemometer:

- Voltage and resistance meter
- RM Young model 18310 anemometer torque disk
- RM Young model 18801 rotational calibration unit
- Calibration and Maintenance Form 2 (CMF2)

Steps to calibrate

Refer to section 2.2 of this procedure for the calibration steps.

Maintenance steps

Refer to section 2.2 of this procedure for the maintenance steps.

3.0 Instruments for Measuring Atmospheric State Variables

3.1 Temperature instrument / radiation shield assembly

Instrument description

The Met One, Inc., temperature measurement assembly consists of two parts:

- Model 076 solar radiation shield
- Model 060A-2 thermistor temperature instrument (also probe)

The model 076 solar radiation shield is mounted vertically, drawing air in from the bottom and exhausting the air at the top. The top portion is a metal shield that is shaped and acts like an umbrella. This structure provides the mounting hardware and houses the aspirator fan. Beneath the top portion is the thermistor probe housing, which is formed by concentric metal tubes through which the aspirator draws air. The space between the two tubes is a path for high-volume “wash” air that dissipates heat caused by solar energy deposited on the surface of the outer metal tube. The thermistor is mounted within the inner tube, which has a restricted air flow (to ensure the high-volume wash air).

The vertical alignment of this assembly obviates a problem found with horizontal radiation shield designs, which are sensitive to wind direction. A wind which bucks the wash air flow will cause the temperature sensor to respond to solar heating of the radiation shield. The powered aspirator fan is much better than naturally aspirated solar radiation shields, which can overheat on calm sunny days.

The datalogger provides the excitation for the thermistor probes and records the measurements through a precision resistor network for each probe. The probes are excited only momentarily for measurements.

Specifications

The instrument specifications are as follows:

- Range: -50° C to +50° C
- Sensitivity: 5.6 mV/° C
- Accuracy: ± 0.2° C
- Resolution: ± 0.1° C

3.1 Temperature instrument / radiation shield assembly, continued

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the temperature probes:

- Dewar flask
- Precision glass mercury reference thermometer (see section 8.2, Precision Mercury Thermometer)
- Group of probes to be calibrated
- Transducer data sheet showing resistance vs temperature
- Resistance meter
- Voice tape recorder
- Calibration and Maintenance Form 3 (CMF3)
- Calibration and Maintenance Form 4 (CMF4)

Steps to calibrate

To check and calibrate the probes, perform the following steps:

Step	Action
1	Read the manuals and manufacturers' literature on the instrument and calibration equipment before proceeding.
2	Use a Dewar flask to control heat loss (or gain) and minimize bath temperature gradients. The flask dimensions are such that the sensor probe tips will be at midvolume when inserted in the flask. Fill the flask with an ice/water bath (temperature 0° ± 0.1° C).
3	Place the temperature probes in the bath with the reference thermometer. Insert the thermometer bulb in the flask to the same depth as the sensor tips.
4	After the temperature has stabilized, adjust the temperature by adding warmer or colder water until the desired temperature is reached. If you are using ice and water, no temperature adjustment is needed.
5	When the bath temperature has stabilized, record the temperature of the bath, as measured by the reference thermometer.
6	Promptly measure and record the resistance of each probe with the voltage/resistance meter. To speed this process, and therefore avoid bath temperature drift, use a voice tape recorder to record the measurements.
7	Promptly record the temperature of the bath, as measured by the reference thermometer, at the end of the series of resistance measurements.
8	Repeat the series of measurements, steps 5 - 7, two more times.
9	Transcribe the measurements to CMF4, page 2.
10	Repeat steps 3 - 9 two more times using 15° C ± 2.0° C and 30° C ± 2.0° C in place of 0° ± 0.1° C in Step 4.

Steps continued on next page.

3.1 Temperature instrument / radiation shield assembly, continued

Step	Action
11	For each of the averaged, reference temperatures, use the transducer data sheet to obtain the resistance vs temperature function for the temperature probe. The transducer data sheet increments by whole degrees, so it is necessary to do a linear interpolation, by tenths of a degree, between two temperatures which span the reference temperature. Enter the values on the appropriate table of CMF4, page 2.
12	Use the average of the three measurements made for each probe at one bath temperature to determine, from the table created in Step 11, the temperature measured by the probe.
13	Transcribe the probe temperature values for each bath to CMF4, page 1.
14	For a postcalibration (postcal.), group the probes according to the tower from which the probes were removed and enter the serial numbers in the tower assignment table of CMF4, page 1. Transcribe the required information to a CMF3 and then insert this postcal. form in the appropriate tower activity log section.
15	For a pre-cal., group the probes and assign a matched set to one tower and enter the serial numbers in the tower assignment table of CMF4, page 1. Then transcribe the information to a CMF3. When the temperature probes are installed on a tower, insert this form in the appropriate tower activity log section. For a pre-cal. log, enter the installation date, time, and signature.
16	Insert the CMF4 in the General Calibration Information notebook, temperature section.

Maintenance steps

To maintain the temperature instrument/radiation shield assembly, perform the following steps:

Step	Action
1	Replace all of the tower site aspirator fans at every fourth meteorological-instrument-calibration cycle (i.e. 4 year interval) to ensure reliable operation.
2	Apply automotive wax to the painted surfaces annually for protection and to help reduce ice buildup.
3	Replace all the tower site temperature probes at the annual meteorological instrument calibration cycle.

3.2 Atmospheric pressure instrument

Instrument description

The Setra Systems, Inc., Model 270 pressure instrument uses a variable capacitance ceramic sensor in the form of a capsule with gold electrodes on the inside surfaces and high vacuum internal reference. The package includes interface electronics to provide high sensitivity, which eases interfacing.

Specifications

The instrument specifications are as follows:

- Range: 600 to 1,100 millibars (mbar)
- Sensitivity: 10 mV/mbar
- Accuracy: ± 0.3 mbar, over 6 months
- Resolution: 0.01% full-scale range (limited by noise)

For additional information, see instrument specifications and data sheet

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the atmospheric pressure instrument:

- Calibration and Maintenance Form 3 (CMF3)

Steps to calibrate and maintain

To calibrate and maintain the atmospheric pressure instrument, perform the following steps:

Step	Action
1	Exchange the pressure instruments at the annual meteorological instrumentation calibration cycle. Maintain an operational spare to minimize the downtime.
2	Exchange the tower unit with an operational spare and submit the removed instrument to the Standards and Calibration group (ESH-9) for recertification.
3	Fill out a CMF3 when a new instrument is installed at the tower site and insert this form in the appropriate section of the tower activity log notebook.

3.3 Relative humidity instrument

Instrument description

The Rotronic Instrument Corp. Model MP100 relative humidity (RH) instrument contains a hygroscopic variable capacitance sensor with an electronic interface which provides the linear high-level output.

Specifications

The instrument specifications are as follows:

Range: 0 to 100% RH
Sensitivity: 10 mV/ % RH
Accuracy: < ± 1% RH
Resolution: < ± 0.5% RH

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the relative humidity instrument:

- Calibration and Maintenance Form 3 (CMF3)

Steps to calibrate and maintain

To calibrate and maintain the relative humidity instrument, perform the following steps:

Step	Action
1	Exchange the RH instruments at the annual meteorological instrumentation calibration cycle. The instrument operational spares inventory minimizes downtime.
2	Return the old instruments, removed after 1 year of service, to Rotronic Instrument Corporation for recertification.
3	Fill out a CMF3 when a new instrument is installed at a tower site and insert this form in the appropriate section of the tower activity log notebook.

3.4 Absolute humidity instrument

Instrument description

The IR-2000, manufactured by the Ophir Corporation, is a folded-path optical infrared hygrometer. It operates by using two different IR wavelengths, or bands, and a differential measurement system. The instrument determines atmospheric water vapor content by the absorption of energy in the primary IR band. The secondary IR band, which is not absorbed by water vapor, provides a continuous monitor of the quality of the measurement system and optical path. The IR-2000 then does a differential measurement, which compensates for electronic and optical sensitivity changes, fog, or haze.

The infrared beams traverse the open volume from the IR source to a mirror and back to an IR sensor for a total measurement path length of 56.2 cm. The instrument's fundamental measurement is absolute humidity (g/m^3). The IR-2000 digital data rate is 20 Hz but with the digital-to-analog converter, which is necessary for these measurements, the data rate is 1 Hz. The instrument is designed for continuous operation in all weather and provides a measurement that is used to calculate atmospheric evaporative heat flux.

Specifications

The instrument specifications are as follows:

Range: 0 to 50 g/m^3
Sensitivity: 100 mV/g/m^3
Accuracy (dew point reference): 1.0° C above 0° C and 1.5° C below 0° C

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the relative humidity instrument:

- Calibration and Maintenance Form (CMF3)

Steps to calibrate

To calibrate the absolute humidity instrument, perform the following steps:

Step	Action
1	Return the hygrometer to the manufacturer for recertification at the annual meteorological instrumentation calibration cycle.
2	Complete the CMF3 as required when a new instrument is installed at a tower site and insert this form in the appropriate section of the tower activity log notebook.

3.4 Absolute humidity instrument, continued

Maintenance steps

To maintain the absolute humidity instrument, perform the following steps:

Step	Action
1	Heavy wet snow falling in calm conditions can accumulate on the mirror. This doesn't happen often and usually will clear with sunshine and wind, but it may be necessary to clear the snow by hand.
2	During weekly site visits, verify that the IR-2000 analog display is updating at the one second data rate.

3.5 Fuel moisture transducer

Overview

The fuel moisture transducer is installed at TA-6 and is on a separate datalogger. The Handar fuel moisture stick is returned annually to the manufacturer for the installation of a new wood dowel. This measurement is performed only in the summer fire season and can be shut down through the winter.

Steps to calibrate fuel moisture transducer

To calibrate the fuel moisture transducer, perform the following steps:

Step	Action
1	In the spring of the year, remove the fuel stick transducer assembly and return it to the manufacturer to have the assembly fitted with a new fuel stick (dowel) for the next season.
2	Install the refurbished fuel stick transducer that had been returned to the manufacturer the previous spring.
3	Make an entry in the Tower Log Notebook citing: • the work completed, • a description of any adjustments made, • data editing requirements, • the period for which the edits are required, and • any other pertinent information. Sign and date the entry.

4.0 Instruments for Measuring Precipitation-Related Variables

4.1 Heated tipping-bucket precipitation gauge

Instrument description

Precipitation measurements are made with the Weathermeasure model 6010 electrically heated tipping-bucket precipitation gauge. This gauge has a thermostatically controlled electric heater in the collection funnel that melts frozen precipitation, resulting in an actual water-content measurement. Rain measurements do not require the heater system. The measurement device is a teeter-totter mechanism that tips with each one-hundredth of an inch of precipitation collected. A bucket tipping causes a momentary switch closure that is counted by the datalogger, resulting in a totaling of precipitation for the data-output period of 15 minutes.

The gauges are installed with wind screens, which still the air flow over the top of the gauge. A bare rain gauge (i.e., without a wind screen) is expected to underestimate precipitation by 25%. The tipping-bucket gauge selection was made after comparisons with weighing buckets in several locations. The often-slight amounts of precipitation of this semiarid climate promoted the selection of the tipping-bucket because of its better resolution.

The Weathermeasure model 6010 precipitation gauge is cleaned, inspected, and calibrated every 6 months. This interval is chosen not so much because the mechanism needs adjustment, but because it needs cleaning. Bugs, dirt, and dissolved solids precipitate out onto the tipping-buckets and can imbalance the system.

Specifications

The instrument specifications are as follows:

Range:	unlimited
Sensitivity:	1 tip/0.01 inch
Accuracy:	0.5% at 0.5 inch/hour
Resolution:	0.01 inch

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the heated tipping-bucket precipitation gauge:

- Pipette, 10 ml
- Deionized water
- Duster and a small stiff-bristled cleaning brush
- Ethanol
- Kimwipes
- Calibration and Maintenance Form 5 (CMF5)

4.1 Heated tipping-bucket precipitation gauge, continued

Steps to calibrate

To calibrate the tipping-bucket, perform the following steps:

Step	Action
1	Use a pipette to slowly drop 8.0 ml of water into the collecting funnel. This amount corresponds to 0.01 in. of precipitation.
2	Repeat Step 1 at least three more times to thoroughly cycle the mechanism. Record the as-is status of the gauge on CMF5.
3	Open the mechanism to clean and examine. Dust out as required.
4	Clean the buckets with alcohol and a brush to remove the dissolved solids.
5	Check the leveling indicator on the bottom to verify that the gauge is level; adjust if necessary.
6	Check proper operation of the ac power source, thermostat, and heaters using a voltage and resistance meter. Check heater circuit continuity and the 120-V ac power outlet within the gauge by advancing the thermostat until it actuates. Reset the thermostat to the normal operating temperature when the test is complete.
7	Repeat steps 1 and 2 to verify proper operation. If not within specifications, follow the calibration procedure given in the gauge manual.
8	Fill out CMF5 as required for this procedure.
9	Insert the CMF5 in the appropriate section of the tower activity log notebook or rain gauges notebook for rain gauges not associated with a tower.

4.2 Tipping-bucket precipitation gauge with antifreeze system

Instrument description

Precipitation measurements at two remote sites on the mountain, called UPJCN and UWACN, use a different tipping bucket gauge that utilizes an antifreeze system for frozen precipitation instead of an electrical heater. The gauge is a Texas Electronics model TE525WS tipping bucket combined with a model CS705 antifreeze reservoir system. The frozen precipitation caught in the CS705 catch tube dissolves into the antifreeze. As the snow melts, the liquid flows through an overflow tube into the TE525WS gauge. The frozen precipitation is thus measured by the tipping bucket.

Specifications

The CS705 has inherent delays caused by three factors: temperatures of the air and the liquid in the reservoir; surface tension in the overflow tube; and the form of the precipitation. For rainfall at 25°C, a delay of minutes is expected after the gauge receives a minimum accumulation of about 0.03”. For snowfall, delays of hours can occur depending upon the air temperature and density of the snow. Eventually, all precipitation falling into the CS705 catch tube will be measured.

Antifreeze used

The antifreeze used in the CS705 reservoir is 1:1 propylene glycol and ethanol (PGE). The PGE/precipitation which flows through the tipping bucket rain gauge is caught in a storage container for proper disposal. The CS705 is installed and charged with antifreeze in the fall of the year and removed in the spring since the CS705 is not necessary the warmer months. If a winter season is particularly cold and has a large amount of precipitation, it may be necessary to recharge the CS705 with antifreeze because the existing antifreeze has been diluted too much to properly melt frozen precipitation.

Steps to calibrate and maintain

To calibrate and maintain the snow depth gauge, perform the following steps.

Step	Action
1	Follow steps 1-5 and 7-9 as described in section 4.1, “Steps to calibrate” for the TE525WS tipping bucket rain gauge calibration.
2	In the fall, when the CS705 is installed on the tipping bucket, add antifreeze to the reservoir until there is flow through the overflow tube into the TE525WS tipping bucket gauge.

4.3 Snow depth gauge

Instrument description

The SR50 snow depth gauge is manufactured by Campbell Scientific, Inc. The gauge is used in conjunction with a Campbell Scientific 21X datalogger to provide continuous measurement of snow on the ground. The datalogger controls the operation of the SR50 gauge and logs the data as specified by the user.

The gauge installed at TA-6 is suspended from a boom attached to an 8-foot high tower section embedded in the ground. The gauge is 83.4 inches above the ground. The datalogger is programmed to record this distance as zero. Any decrease in this distance is snow on the ground recorded in inches.

Specifications

The gauge specifications are as follows:

Range:	2 feet to 33 feet
Accuracy:	± 0.4 inch
Resolution:	± 0.2 inch

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the snow depth gauge:

- carpenter's level
- measuring tape
- cardboard box (approximately 12"x12"x18")
- desiccant pack (replaced annually)
- tool for cutting small area of tall grass
- Calibration and Maintenance Form 5 (CMF5)

Steps to calibrate and maintain

To calibrate and maintain the snow depth gauge, perform the following steps.

Step	Action
1	Read the manual and manufacturer's literature on the SR50 before proceeding.
2	Use a carpenter's level to check the snow gauge plumb.
3	With no snow on the ground, check the datalogger output, which should be zero ± 0.4". To adjust the zero value, change the offset in the datalogger program.
4	Place a cardboard box on the ground under the SR50 gauge and read the measurement from the datalogger. This measurement should equal the box height ± 0.4".

Steps continued on next page.

4.3 Snow depth gauge, continued

Step	Action
5	Replace the desiccant packet within the SR50 at the annual meteorological instrumentation calibration cycle.
6	Fill out CMF5 as required for this procedure.
7	There are no SR50 adjustments which the user can make. If the SR50 fails the calibration, return it to the manufacturer for repair.
8	Insert the CMF5 in the appropriate section of the tower activity log notebook.
9	The SR50 will measure the height of the grass. Late in the fall it is necessary to cut the grass very closely to the ground in a 36” diameter circle beneath the SR50.

4.4 Lightning detector

Instrument description

The M-10/P-10 lightning detector, manufactured by Airborne Research Associates, detects cloud-to-cloud and cloud-to-ground lightning. The M-10 operation switch is set to require coincidence of an optical flash and electric field change (rf). The detector has a range adjustment to limit the detection distance. This range adjustment is not quantified because the actual detection distance depends upon siting and strength of the lightning flash or strike. The only other adjustment is the volume control for an audible warning.

The M-10 response time is such that it detects the individual strokes in what would be called a single lightning strike. Therefore the lightning strike count recorded by the datalogger will be inflated. At this point, the major interest is in daily lightning occurrence at Los Alamos.

Specifications

The M-10/P-10 system specifications are as follows:

Range: 0 to approximately 3 miles (minimum range position)
Range: 0 to approximately 30 miles (maximum range position)
Range as used at LANL: detuned to limit detection to the local area.
Detection mode: both (optical & rf)

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the lightning detector:

- Calibration and Maintenance Form 5 (CMF5)

Steps to calibrate and maintain

To calibrate and maintain the lightning detector, perform the following steps.

Step	Action
1	Read the manual and manufacturer’s literature on this instrument before proceeding.
2	The detector range is the only calibration required. Set the range to position C. This is probably a 5-to 10-mile detection range. Once set, this should not require further adjustment.
3	Test the detector by removing the P-10 plastic cover, touching the brass plate on top of the M-10 with one hand and flicking the other hand quickly over the top of the M-10 viewing lens. The fingers of the moving hand should be splayed to provide quickly varying light flashes to the M-10. The M-10 will “beep” if it accepts this test, indicating proper operation.

Steps continued on next page.

4.4 Lightning detector, continued

Step	Action
4	Maintain the detector by applying a coat of wax to the P-10 plastic cover twice a year.
5	Fill out CMF5 as required by this procedure.
6	Insert the CMF5 in the appropriate section of the tower activity log notebook.

5.0 Instruments for Measuring Radiative Fluxes

5.1 Pyranometer

Instrument description

The Eppley Laboratory, Inc. model 8-48 pyranometer is used to measure shortwave visible radiation. These pyranometers are installed upward-facing to measure incoming shortwave visible radiation and downward-facing to measure reflected shortwave visible radiation from the ground. The pyranometers measure total solar radiation (direct and diffuse) falling on a flat horizontal plane. The optical glass window transmits energy to the sensor from 0.285 to 2.8 microns.

The value shown for sensitivity is typical, but each pyranometer has its own sensitivity value, determined by manufacturer's calibration, which is programmed into the datalogger as a calibration value.

Specifications

The specifications are as follows:

Range: 0 to 1400 W/m^2
Sensitivity: approx. 10 μV/W/m^2
Accuracy: Cosine response, ± 3.5% from normalization (0° -70° zenith angle) and ± 6.5% (70° - 80° zenith angle). This accuracy accounts for temperature dependence.

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the pyranometer:

- Calibration and Maintenance Form 6 (CMF6)

Steps to calibrate and maintain

To calibrate and maintain the shortwave radiation instrument, perform the following steps.

Step	Action
1	Instrument recertification can follow two courses: 1) return the instrument to the manufacturer, annually, for recertification (Step 1a), or 2) evaluate the instrument's performance by co-location with a recently manufacturer recertified unit (Step 1b).
1a	If all the instruments are going to be returned to the manufacturer for recertification, exchange the existing instrument at a tower with a newly recertified unit until all of the instruments have been manufacturer recertified.

Steps continued on next page.

5.1 **Pyranometer**, continued

Step	Action
1b	For instrument verification by co-location -- an operational spare instrument is returned to the factory for recertification. This reference or standard instrument is then co-located with the instrument at each tower site. The output of this standard is compared with the recorded output of the tower site instrument. If necessary, adjustment of the datalogger multiplier may be made to compensate for aging of the tower site instrument.
2	Clean the optical dome during the first week of each month.
3	When a new pyranometer is installed, change the datalogger input program multiplier to match the new pyranometer.
4	Fill out a CMF6 when any calibration work is completed at a tower site and insert this form in the appropriate section of the tower activity notebook.

5.2 Pyrgeometer

Instrument description

The Eppley Laboratory, Inc. model PIR (precision infrared radiometer) pyrgeometer is used to measure long-wave radiation. Pyrgeometers are installed upward-facing to measure incoming infrared radiation and downward-facing to measure outgoing infrared radiation. The pyrgeometers are temperature compensated internally. The silicon window transmits energy to the sensor from 4 to 50 microns.

Specifications

The specifications are as follows:

Range: 0 to 700 W/m^2
Sensitivity: approx. 4 μV/W/m^2
Accuracy: Cosine response, better than 6% from normalization. This accuracy accounts for temperature dependence.

The value shown for sensitivity is typical, but each pyranometer has its own sensitivity value, determined by manufacturer's calibration, which is programmed into the datalogger as a calibration value.

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the pyrgeometer:

- mercury battery number RM1R
- Calibration and Maintenance Form 6 (CMF6)

Steps to calibrate and maintain

To calibrate and maintain the long-wave radiation instrument, perform the following steps.

Step	Action
1	Instrument recertification can follow two courses: 1) return the instrument to the manufacturer annually for recertification (Step 1a), or 2) evaluate the instrument's performance by co-location with a recently manufacturer recertified unit (Step 1b).
1a	If all the instruments are going to be returned to the manufacturer for recertification, exchange the existing instrument at a tower with a newly recertified unit until all of the instruments have been manufacturer recertified.

Steps continued on next page.

5.2 **Pyrgeometer**, continued

Step	Action
1b	For instrument verification by co-location -- an operational spare instrument is returned to the factory for recertification. This reference or standard instrument is then co-located with the instrument at each tower site. The output of this standard is compared with the recorded output of the tower site instrument. If necessary, adjustment of the datalogger multiplier may be made to compensate for aging of the tower site instrument.
2	Clean the optical dome during the first week of each month.
3	When a new pyrgeometer is installed, change the datalogger input program multiplier to match the new pyrgeometer.
4	Every 6 months, replace the mercury battery for the pyrgeometer’s internal temperature compensation circuit.
5	Fill out a CMF6 when any calibration work is completed at a tower site and insert this form in the appropriate section of the tower activity log notebook.

6.0 Instruments for Measuring Subsurface Variables

Overview

Subsurface measurements are made at the TA-6 and TA-54 tower sites. Optimal transducer installation is in undisturbed soil, therefore instruments will not be removed for periodic work such as calibrations. These instruments will only be removed if there is evidence of damage or other malfunction, which can be determined by intra-comparison of measurements. This is possible because of the number of instruments measuring the same variable under slightly different conditions.

The measurements made at the two tower sites are identical. Temperature is measured at 2 and 6-cm depths in two different locations about 1.5-m apart; two ground heat flux transducers measure fluxes at the 1.5-m separated locations; soil moisture is measured with two instruments which are in between the two 1.5-m separated locations; and temperature is measured at a 10-cm depth at this in-between location.

6.1 Soil temperature probe

Instrument description

The soil temperature probe provided by Met One, Inc. is the model P8788 thermistor temperature probe. The instrument contains the same thermistor provided in the air temperature probe described in section 3.1. The P8788 is a special order probe with a minimal thermal mass housing.

Specifications

The instrument specifications are as follows:

Range: -50 to +50° C
Sensitivity: 5.60 mV/° C
Accuracy: ± 0.2° C
Resolution: ± 0.1° C

Calibration and maintenance

Refer to section 3.1 for the equipment required for calibrating and maintaining the soil temperature probe.

Refer to section 3.1 for the calibration procedure.

Steps to maintain

As stated in the section 6.0 Overview, these instruments will not be disturbed unless data indicates that an instrument is malfunctioning. Refer to procedure ESH-17-404 for instructions on removal or these instruments.

6.2 Soil moisture instrument

Instrument description

The soil moisture instrument is the Campbell Scientific model CS615 Water Content Reflectometer. The CS615 measures the time it takes for an electrical pulse to travel the 30-cm length of the probe rods which are inserted into the soil. The transit time is determined by the dielectric constant of the soil, which is primarily controlled by the moisture in the soil. The datalogger contains the algorithm to provide the final volumetric water content as a percentage.

Specifications

The CS615 manual attempts to define and evaluate all of the variables that control the range, resolution, and accuracy of the measurement. The added expense, which would be required to achieve the optimal performance, is not necessary for this subsurface measurement program. We are primarily interested in calculating the energy storage term for the layer of soil above the ground flux heat plates.

To properly measure soil moisture, it would require deploying many CS615s spread over a large area at the TA-6 and TA-54 sites. But we do provide these measurements of soil moisture in our data set for those who might find it useful.

Bearing in mind the instrument specifications are as follows:

Range: approx. 0 to 50%
Accuracy: > ± 2% for LANL application

Calibration and maintenance

The CS615 electronic package is factory-sealed in epoxy and cannot be calibrated, maintained, or repaired. Calibration is as received from the factory. The only adjustment is to ensure the probe rods are straight and parallel during installation in the ground. When QC data indicates the instrument is not performing properly, the instrument is removed and a new CS615 is installed.

Equipment and supplies for operational verification

The following equipment and supplies are needed for checking the operation of the CS615 instrument:

- Large beaker approximately 3 in. inside diameter by 16 in. deep
- 21X datalogger programmed to accept the CS615 instruments signal

6.2 Soil moisture instrument, continued

Steps to verify operation

To verify operational capability, perform the following steps:

Step	Action
1	Program the 21X datalogger in accordance with the CS615 manual.
2	Connect the CS615 to be evaluated to the datalogger, per the CS615 manual.
3	Fill the beaker with water.
4	Hold the CS615 in air and note the reading from the datalogger. **Note**: For a good CS615, the reading should be about 2%.
5	Suspend the CS615 in the center of the beaker with the probe rods totally immersed in the water. **Note**: For a good CS615, the reading should be about 80%.

6.3 Ground heat flux instrument

Instrument description

The ground heat flux instrument is the Campbell Scientific model HFT3 thermopile heat flow instrument. Ground heat flux is calculated in the datalogger by using the calibration coefficient, which is determined by the manufacturer for each instrument.

Specifications

Instrument specifications are as follows:

Range: ± 1500 W/m^2
Sensitivity: approx. 40 $W/m^2/mV$
Accuracy: ± 5%, nominal

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the ground heat flux instrument:

- Calibration and Maintenance Form 7 (CMF7)

Steps to maintain and calibrate

To maintain and calibrate the ground heat flux instrument, perform the following steps.

Step	Action
1	Return the instrument to the manufacturer as required.
2	When a new ground heat flux instrument is installed, change the datalogger input program multiplier to match the new unit.
3	Fill out a CMF7 when a new instrument is installed at a tower site and insert this form in the appropriate section of the tower activity log notebook.

7.0 Data Acquisition Systems

7.1 Dataloggers

Instrument description

The Campbell Scientific, Inc. datalogger (model 7X and 21X) design is such that one of the first operations performed is an analog-to-digital (A/D) conversion. Thereafter, all signal processing is digital and does not require adjustment. In fact, the dataloggers are so stable that it has not been necessary to adjust the A/D calibration for any dataloggers used for this network.

Specifications

Some of the specifications for the 7X and 21X are as follows:

Voltage measurement accuracy: ± 0.02% of full-scale range (FSR) from -25° C to +5° C. and ± 0.01% of FSR from 0° C to +40° C.

Range (volts)	7X Resolution (microvolts)	21X Resolution (microvolts)
± 5.000	166.0	333.0
± 1.500	50.0	n.a.
± 0.500	16.6	33.3
± 0.150	5.0	n.a.
± 0.050	1.66	3.33
± 0.015	0.5	n.a.

Input noise: 7X is 43 nanovolts rms and 21X is 100 nanovolts rms

Equipment and supplies for calibration and maintenance

The following equipment and supplies are needed for calibrating and maintaining the dataloggers:

- Precision adjustable voltage source
- Voltage and resistance meter
- Precision 100-to-1 voltage divider
- Calibration and Maintenance Form (CMF8)

Steps to maintain and calibrate

To maintain and calibrate the dataloggers, perform the following steps.

Step	Action
1	Read all of the manuals and manufacturers' literature on the datalogger and calibration equipment before proceeding.

Steps continued on next page.

7.1 Dataloggers, continued

Step	Action
2	Using an accurate, stable, adjustable voltage source and a calibrated voltmeter to verify the voltage source, check the datalogger from input (voltage source) to output (display) for parity. Execute steps a. through d.
a.	Perform zero and full scale signal injections for each input channel.
b.	Record the datalogger output for each test on CMF8, being careful to note and/or include the data channels, multipliers, and offsets. Completely fill out the CMF8, as required.
c.	If the datalogger is not within specifications, adjust the A/D per the procedures in the datalogger manual or return the unit to the manufacturer for repair and calibration. **Note:** The history of the dataloggers is such that the calibration procedure, datalogger input program, voltage source, and voltmeter calibration should be double checked before any datalogger adjustment is attempted.
d.	Insert this CMF8 in the appropriate section of the tower activity log notebook.

7.2 Sodar data collection computer at TA-6

Computer description

The sodar personal computer (PC), which is located at the TA-6 meteorological tower site, is an IBM-PC clone with a 386 processor and color monitor, 100-Mb Iomega Zip drive for data storage, and two serial communication ports. The PC runs a DOS operating system and the AeroVironment data collection software called DOPLMAIN, version 2.97, continuously. In case of a power failure, the DOPLMAIN software will reload automatically and resume data collection when the power is restored.

Computer maintenance and calibration

No calibration is required, and maintenance is done when something fails. Data "maintenance" consists of weekly data transfers to alternating c: drive directories called "temp1" and "temp2" and to the Zip drive. The data storage by DOPLMAIN is to a directory called "data." This directory is cleared after the data have been transferred as described above. The Zip drive cartridges are retained as the backup archival storage of DOPLMAIN-created data files. The data is read from these cartridges and stored on the ESH-17 Meteorology Monitoring Project's work station called Sibyl.

7.3 Sodar backup computer at TA-59

Computer description

The backup sodar data collection personal computer (PC), at TA-59, is also an IBM-PC clone with a 486 processor and color monitor. The PC runs a DOS operating system and DATAMAN software, which continuously displays four graphic wind profiles, which are updated with each new data transfer from the sodar (every 15 minutes).

The PC will reload the DATAMAN software after a power failure but cannot retrieve data which were generated during the outage. The data generated by the sodar are sent without any “hand-shaking” with the intended receptor. For this reason, this backup PC is located at TA-59 to also collect the sodar data and provide graphic displays. However, the TA-6 PC data are collected with the AeroVironment DOPLMAIN software, which has a different format than the DATAMAN software used by the backup PC at TA-59. To recover data lost to the prime TA-6 PC, another program is invoked to retrieve data from the TA-59 backup PC.

DATAMAN software creates daily files which contain all the data generated by the sodar in the original format (these files are similar to DOPLMAIN-created files). DATAMAN also creates a monthly archive file. Only the DOPLMAIN clone files are needed for backup.

Computer maintenance and calibration

No calibration is required, and maintenance is done when something fails.

The DATAMAN files (the monthly archival file and daily DOPLMAIN clone files) are simply deleted each month after they are no longer needed. The only possible use for the clone files would be to replace data missing from the TA-6 DOPLMAIN-created data files.

7.4 Tower dial-up computer

Computer description

The tower dial-up computer, at TA-59 is a Hewlett Packard workstation called Sibyl. This computer uses Soft PC to run the Campbell Scientific Inc. software (TELCOM) for data collection. The TELCOM software runs continuously, collecting the latest data every 15 minutes from every tower datalogger. The software calls the tower dataloggers, collects the data, and writes the collected data to the appropriate tower file.

The dataloggers store the meteorological data in ring memory, which means that as the memory is filled, the oldest data are overwritten by the newest data. Typically, there are six days worth of data within this memory. So, in the event of power, telephone, or computer failures, the data are automatically recovered from the datalogger by TELCOM when service is restored. If the outage were to go beyond the ring data storage of the datalogger, then it would be necessary to retrieve the data from the affected tower manually with a solid state storage module.

8.0 Test Instruments Used in Calibrating Meteorological Instruments

8.1 Voltage and resistance meter

Background and instrument description

Voltage and resistance measurements are necessary to calibrate the various meteorological instruments. The voltage and resistance meter must provide 4-5 digit resolution, with accuracy that is better than sensor requirements.

Specifications

The instrument specifications are as follows:

dc voltmeter accuracy:	± (0.05% of reading +0.015% of full scale)
ohmmeter accuracy:	± (0.15% of reading +0.015% of full scale)

Steps to calibrate the meter

To calibrate the voltage and resistance meter, return the instrument to the Los Alamos National Laboratory Standards and Calibration group for calibration. The calibration cycle is established and controlled by this group. This group provides calibration services and maintains the records on the calibration. The group will attach a sticker to the instrument indicating the calibration expiration date and will send a sheet detailing the calibration specifications.

8.2 Precision mercury thermometer

Instrument description

Use this mercury-in-glass thermometer as a transfer standard to calibrate the meteorological temperature sensors. The thermometer, model ASTM 63C, is manufactured by Ertco.

Specifications

The instrument specifications are as follows:

Range: -8° C to +32° C
Division: 0.1° C
Calibration uncertainty: ± 0.1° C

Steps to calibrate the thermometer

To calibrate the precision mercury thermometer, return the instrument to the Los Alamos National Laboratory Standards and Calibration group for calibration. The calibration cycle is established and controlled by this group. This group provides calibration services and maintains the records on the calibration. The group will attach a sticker to the instrument indicating the calibration expiration date and will send a sheet detailing the calibration specifications.

8.3 Propeller anemometer wind speed calibrators

Calibrator description

The rotational calibration units are required to calibrate the RM Young wind-speed sensors. The models 27230, 27231 and 27232 calibrators are simply synchronous 60-Hz ac motors that rotate at constant speeds of 300, 1800 and 3600 rpm, respectively. These output speeds are directly proportional to the applied power frequency, which is, in itself, a critically controlled standard. The 18801 is a selectable speed calibration unit with a speed range of 100 to 10,000 rpm.

Steps to calibrate

To calibrate the propeller anemometer wind speed calibrators, return the instrument to the Los Alamos National Laboratory Standards and Calibration group for calibration. The calibration cycle is established and controlled by this group. This group provides calibration services and maintains the records on the calibration. The group will attach a sticker to the instrument indicating the calibration expiration date and will send a sheet detailing the calibration specifications.

8.4 Propeller anemometer vane angle calibrator

Calibrator description

The RM Young model 1722 vane angle calibrator is necessary to calibrate the azimuth measuring portion of the RM Young model 35005 propeller anemometer. The vane angle calibrator is a bench-testing fixture that holds the propeller vane and allows the vane to be turned through 360 degrees with the angle mechanically measured on a protractor. This mechanically measured angle is then compared with the electrical output of the potentiometer. This is a mechanical device which does not have or require any calibration or adjustment.

8.5 Propvane azimuthal siting scope

Background

The RM Young model 35005 propvane has a locating notch in its mounting base which provides a reference for azimuthal orientation. The model 1722 vane angle calibrator has a corresponding pin that engages this notch when a propvane is calibrated. The tower boom mounting fixture has an orientation ring which also has a locating pin. In this way, a propvane can be taken from the model 1722 to a tower and be oriented to true north with great accuracy, provided the boom mounting fixture orientation ring has been properly aligned.

A compass cannot be used for boom mounting fixture orientation because of the steel tower structure. Alignment to a visual landmark, using the “az-scope” (description follows), is the preferred technique. The “az-scope” requires locating the tower and the landmark on a map for the determination of the azimuthal alignment angle.

Azimuthal scope description

The “az-scope” is a “home-built” azimuthal alignment device designed for this purpose. The az-scope consists of a surveyor's transit mounted to a salvaged propvane base. Basically, the az-scope is placed on a tower boom mounting fixture with the map-determined azimuthal angle from true north (to the landmark) set and locked into the transit and a loosely mounted orientation ring installed. The az-scope/orientation ring, is rotated as an assembly, until the az-scope is sighted on the landmark. The orientation ring is tightened to the boom mounting fixture. When the az-scope is removed, the orientation ring will ensure that when a propvane is installed, it will be properly oriented to true north.

Equipment and supplies required to calibrate the azimuthal scope

The following equipment and supplies are needed for calibrating and maintaining the ground heat azimuthal siting scope:

- An open area with a good distant landmark, such as at the TA-6 tower site and the distant TA-55 radio tower.
- A low table, like the old typewriter table found in the TA-6 instrument shed.
- The RM Young model 1722 vane angle calibrator.
- A surveyor's transit and tripod.
- A carpenter's level and bulls-eye level.
- Miscellaneous hand tools as required.

8.5 **Propvane azimuthal siting scope,** continued

Steps to calibrate the az-scope

As described, the az-scope is a combination of a transit and salvaged propvane base. The transit's zero degree mark must be aligned with the base unit locator notch for this to be an effective propvane alignment tool. The steps for achieving this alignment are as follows:

Step	Action
1	Mount a propvane on the model 1722 and set and lock the propvane to zero degrees (north) as read on the model 1722 protractor. Set this assembly on a low table (about 24" tall) outside in an open area such as at the TA-6 tower site. Carefully level the table and propvane to ensure that the propvane is plumb.
2	Visually align the propvane on a distant object by sighting along the vane to the landmark (the TA-55 radio tower in this test at TA-6).
3	With the surveyor's transit, check the propvane alignment on the distant landmark. Set the transit up on a line formed by the propvane/landmark, about 20 feet behind the propvane. Take care to properly locate the transit on this "line," it will be necessary to set up the transit, do a sighting, move and reset the transit, resight, etc.
4	Once Step 3 is successfully completed, the transit can be "dumped" to sight along the length of the propvane and then on to the distant landmark. The transit provides verification that the propvane (which is set to zero degrees on the model 1722 protractor) is correctly aligned with the landmark.
5	Set and lock the az-scope to zero degrees as read on the az-scope's transit. Without physically disturbing any part of the setup, remove the propvane from the model 1722 and install the az-scope.
6	Check that the az-scope is properly calibrated. If it is, then the landmark will be viewed when a sighting is taken through the az-scope. The az-scope cross-hairs will be centered on the landmark.
7	If Step 6 proves that the az-scope is out of calibration, then loosen the az-scope's lock nuts which attach the transit top to the base unit. Adjust the az-scope by rotating the transit top with respect to the base until the az-scope cross-hairs center on the landmark. Tighten the loosened lock nuts and verify that the az-scope is still in proper adjustment.
8	This is a tedious process. Take care to not disturb the model 1722 or the table upon which it rests.

8.6 Counter/timer

Background and instrument description

Frequency measurements are necessary to calibrate the sodar. The Tektronix model DC504A counter/timer (or equivalent) meets the requirements.

Range:	0 to 10 Mhz
Accuracy:	± 1 count ± time base error x frequency

Calibrating the meter

Return the instrument to the Los Alamos National Laboratory Standards and Calibration group for calibration. The calibration cycle is established and controlled by this group. This group provides calibration services and maintains the records on the calibration. The group will attach a sticker to the instrument indicating the calibration expiration date and will send a sheet detailing the calibration specifications.

9.0 Records Resulting From These Procedures

Records

The following calibration and maintenance records generated as a result of performing these procedures are filed in the appropriate tower activity log notebook within one week of generation:

- CMF1, Instruments for Measuring Wind Variables
- CMF2, Instruments for Measuring Wind Variables
- CMF3, Instruments for Measuring Atmospheric State Variables
- CMF4, Temperature Probe Calibration
- CMF5, Instruments for Measuring Precipitation-Related Variables
- CMF6, Instruments for Measuring Radiative Flux Variables
- CMF7, Instruments for Measuring Subsurface Variables
- CMF8, Data Acquisition System
- CMF9, Sodar

The tower activity log notebooks are maintained as records at TA-59, Building 0001, Room 176.

HAZARD CONTROL PLAN

1. The work to be performed is described in this procedure.
"Calibration and Maintenance of Instruments for the Meteorology Monitoring Project"

2. Describe potential hazards associated with the work (use continuation page if needed).

1. Lightning.
2. Temperature.
3. Sun Exposure.
4. Snakes, spiders, wasps, etc.
5. Slips, trips and falls associated with uneven wet and/or snow-covered surfaces.
6. Use of ladders.
7. Use of hand tools (screw drivers, wrenches, knives, pliers & wire cutters, etc.).
8. Use of hand power tools (drill motors, saber saw, Sawzall, soldering irons, etc.).
9. Work at night.
10. 1:1 propylene glycol : ethanol (PGE) – ingestion, inhalation, skin contact, eye splash

3. For each hazard, list the likelihood and severity, and the resulting initial risk level (before any work controls are applied, as determined according to LIR300-00-01.0, section 7.2)

1. Remote / catastrophic / low
2. Occasional / moderate / low
3. Frequent / negligible / low
4. Improbable / critical / low
5. Occasional / moderate / low
6. Remote / moderate / low
7. Occasional / negligible / minimal
8. Remote / moderate / minimal
9. Improbable / moderate / minimal
10. remote / negligible / minimal

Overall *initial* risk: ☐ Minimal ☒ Low ☐ Medium ☐ High

4. Applicable Laboratory, facility, or activity operational requirements directly related to the work:
☒ None ☐ List: Work Permits required? ☒ No ☐ List:

HAZARD CONTROL PLAN, continued

5. Describe how the hazards listed above will be mitigated (e.g., safety equipment, administrative controls, etc.):

1. The lightning threat must be continuously monitored by the worker. Developing cumulonimbus clouds in the area are a definite indicator that it is time to monitor the lightning threat more closely. The Sweeney static meter is used to monitor this threat -- if the potential gradient exceeds 2,000 volts per meter, it is time to clear the area.
2. Cold temperatures pose a greater threat to the worker. The worker must be aware of the possibility of hypothermia which is exacerbated by wind and wet weather. The worker must dress appropriately for the weather conditions and possible conditions. Since a vehicle is typically at hand, it is easy for the worker to seek shelter and an active heat source.
3. This topic is covered in the Employee Notebook required reading for all employees. Sun exposure can be minimized with proper clothing, such as long sleeves and a brimmed hat. It is also important to use a high number sun screen. The hazard of sun exposure is not just confined to summer.
4. This topic is covered in the Employee Notebook required reading for all employees. The prospect of encounters with snakes and venomous insects requires the worker to be aware of his surroundings. Especially, watch where you step and where you place your hands.

-- *See continuation page* --

6. Knowledge, skills, abilities, and training necessary to safely perform this work (check one or both):

☒ Group-level orientation (per ESH-17-032) and training to this procedure.

☒ Other → See training prerequisites on procedure page 4. Any additional describe here:

7. Any wastes and/or residual materials? (check one) ☒ None ☐ List:

1 :1 propylene glycol : ethanol which will be disposed of by the TA59 Waste Management Coordinator

8. Considering the administrative and engineering controls to be used, the *residual* risk level (as determined according to LIR300-00-01.0, section 7.3.3) is (check one):

☐ Minimal ☒ Low ☐ Medium (requires approval by Division Director)

9. Emergency actions to take in event of control failures or abnormal operation (check one):

☐ None ☒ List:

1. Contact the ESH17 group office.
2. Arrange for appropriate transportation to the hospital or nearest Occupational Medicine Group medical station

.

Signature of preparer of this HCP: This HCP was prepared by a knowledgeable individual and reviewed in accordance with requirements in LIR 300-00-01 and LIR 300-00-02.

________________________ ________________________ ____________

Preparer(s) signature(s) Name(s) (print) /Position Date

Signature by group leader on procedure title page signifies authorization to perform work for personnel properly trained to this procedure. This authorization will be renewed annually and documented in ESH-17 records. Controlled copies are considered authorized. Work will be performed to controlled copies only. This plan and procedure will be revised according to ESH-17-022 and distributed according to ESH-17-030.

HAZARD CONTROL PLAN, continued

Hazard Control Plan continuation page. Give item number being continued.

5. How hazards are mitigated:

5. Slips, trips and falls can occur anywhere and are of greater potential in the field environment where this instrumentation is located. The worker must be aware of his surroundings and use commensurate caution.

6. Ladders are frequently used to access instruments. Ensure that the ladder is properly placed on level ground with a solid footing so that it does not shift when the worker is on the ladder. The ladder must be positioned so that the worker does not have to over-extend and therefore unbalance the ladder. The worker shall not stand on the top two steps of a ladder. Workers will take the laboratory ladder training course.

7. Ensure that hand tools are in good condition and are proper for the application.

8.As with hand tools, ensure that power tools are in good condition and are proper for the application.

9. In the rare event that work is performed after dark, the workers will wear a headlamp style light, carry a flashlight, or aim the vehicle headlights at the work area.

10. Treat the propylene gycol ethanol (PGE) antifreeze solution with the same care required for any chemical. Do not drink PGE. The work is conducted outside, in the open, so inhalation is minimal. When transferring PGE, use water to rinse skin which comes in contact with PGE and use adequate eye protection.

CMF1, Instruments for Measuring Wind Variables

Met. Tower Site Designation ________ ☐ Pre-Cal. ☐ Postcal. (✓)

Name________________________ Signature______________________ Calibration Date________ Activity Log Page No. ___

Wind Speed Instrument Calibration

Serial Number	Tower Level	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	rpm vs. Design Output (mV) 300-400	1800-2400	3600-4800	Passes 0.6 g-cm Torque Test (limit ≤ 0.6) (√)	Comments (problems, adjustments, observations)
					Actual Output, mV/% Error				
									Spin Down Test = _____s (limit > 60 s) Slip Ring Resistance = 0.____ Ω ± 0.___ Ω Boom Level Verification ______ (√) AZ-Scope Verification ______ (√)
									Spin Down Test = ____ s (limit > 60 s) Slip Ring Resistance = 0.____ Ω ± 0.___ Ω Boom Level Verification ______ (√) AZ-Scope Verification ______ (√)
									Spin Down Test = ____ s (limit > 60 s) Slip Ring Resistance = 0.____ Ω ± 0.___ Ω Boom Level Verification ______ (√) AZ-Scope Verification ______ (√)
									Spin Down Test = ____ s (limit > 60 s) Slip Ring Resistance = 0.____ Ω ± 0.___ Ω Boom Level Verification ______ (√) AZ-Scope Verification ______ (√)

Azimuth Instrument Calibration

Serial Number	Tower Level	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	Azimuth Calibration Check Points (insert measured value) 30 °	90 °	180°	270°	330°	0-360° sweep (√)	Comments (problems, adjustments, observations) Site Reference Bearing _________ °
											Torque Test = ___ g-cm (limit ≤ 20 g-cm) Completed Azimuth Balance ___ (√) Reference Bearing ________ °
											Torque Test = ___ g-cm (limit ≤ 20 g-cm) Completed Azimuth Balance ___ (√) Reference Bearing ________ °
											Torque Test = ___ g-cm (limit ≤ 20 g-cm) Completed Azimuth Balance ___ (√) Reference Bearing ________ °
											Torque Test = ___ g-cm (limit ≤ 20 g-cm) Completed Azimuth Balance ___ (√) Reference Bearing ________ °

CMF2, Instruments for Measuring Wind Variables

Met. Tower Site Designation ___________ ☐ Pre-Cal. ☐ Postcal. (✓)

Name_____________________ Signature__________________ Calibration Date_________ Activity Log Page No. _____

SAMPLE

W-Anemometer Calibration

Serial Number	Tower Level	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	rpm vs Design Output (mV) 300-83.3	1800-500	3600-1000	Passes 0.5 g-cm Torque Test (limit ≤ 0.5) (√)	Comments (problems, adjustments, observations)
					Actual Output, mV/% Error				
									Spin Down Test: CW = _____ s CCW =_____ s (limit > 60 s)
									Spin Down Test: CW = _____ s CCW =_____ s (limit > 60 s)
									Spin Down Test: CW = _____ s CCW =_____ s (limit > 60 s)
									Spin Down Test: CW = _____ s CCW =_____ s (limit > 60 s)

Sonic Anemometer Calibration

Serial Number	Tower Level	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	Zero-Air-Tube Calibration Responses u-axis	v-axis	w-axis	Temperature	Comments, Observations, Adjustments

Comparison of Sonic and Level 1 Conventional Instruments, Corresponding 15 Minute Averages

Variable	Sonic Measurements	Level 1 Measurements
T		
W		
U		
θ		

CMF3, Instruments for Measuring Atmospheric State Variables

Met. Tower Site Designation __________ ☐ Pre-Cal. ☐ Postcal. (✓)

Name____________________ Signature_________________ Calibration Date_________ Activity Log Page No. ______

Humidity Instrument Calibration

Mfg. & Model No.	Serial No.	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	Instrument Calibration Date	Comments (problems, adjustments, observations)

Pressure Instrument Calibration

Serial No.	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	Measure and Record Power Supply Voltage 24 vdc $\pm$ 10%	Comments (problems, adjustments, observations)

Temperature Probe Calibration

Serial No.	Tower Level	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	Ice Bath Check: Sensor / Standard	Ambient Comparison: Sensor / Standard	Warm Comparison: Sensor / Standard	Aspirator Operation (√) / No Power Friction Test (√)	Comments (problems, adjustments, observations)

CMF4, Temperature Probe Calibration

(page 1 of 2)

Name________________ Signature_________________ Calibration Date________ Page No._____

	Ice Bath Reference Temperature	Middle Temperature Bath Reference Temp.	Warm Temperature Bath Reference Temp.
Probe S/N	**Probe Response to each Bath ***		

SAMPLE

*** From work sheet, page 2**

TA-6 Assignment	
Probe S/N	Tower Level
	4
	3
	2
	1
	0

TA-41 Assignment	
Probe S/N	Tower Level
	1
	0

TA-49 Assignment	
Probe S/N	Tower Level
	3
	2
	1
	0

TA-53 Assignment	
Probe S/N	Tower Level
	3
	2
	1
	0

TA-54 / WR Assignment	
Probe S/N	Tower Level
	3
	2
	1
	0

CMF4, Temperature Probe Calibration

(page 2 of 2)

Name_________________ Signature_________________ Calibration Date_______ Page No. ____

Ref. Temp.						Resistance vs Temperature (from probe manual) Chart Interpolation	
Start →				Avg. Ref. T.			
End →							
Probe S/N	1st Resistance Reading kΩ	2nd Resistance Reading kΩ	3rd Resistance Reading kΩ	Avg. Resistance Reading kΩ	Resultant Temperature	Resistance kΩ	Temperature Degrees C

Ref. Temp.						Resistance vs Temperature (from probe manual) Chart Interpolation	
Start →				Avg. Ref. T.			
End →							
Probe S/N	1st Resistance Reading kΩ	2nd Resistance Reading kΩ	3rd Resistance Reading kΩ	Avg. Resistance Reading kΩ	Resultant Temperature	Resistance kΩ	Temperature Degrees C

SAMPLE

Ref. Temp.						Resistance vs Temperature (from probe manual) Chart Interpolation	
Start →				Avg. Ref. T.			
End →							
Probe S/N	1st Resistance Reading kΩ	2nd Resistance Reading kΩ	3rd Resistance Reading kΩ	Avg. Resistance Reading kΩ	Resultant Temperature	Resistance kΩ	Temperature Degrees C

CMF5, Instruments for Measuring Precipitation-Related Variables

Met. Tower Site Designation ____________ ☐ Pre-Cal. ☐ Postcal. (✓)

Name____________________ Signature__________________ Calibration Date________ Activity Log Page No. _______

Precipitation Gauge Calibration

Date	Time	Person	Pre-calibrate Gauge[1]	Level Gauge (√)	ac Pwr Applied (√)	Check Heater Circuits (√)	Clean Gauge (√)	Calibrate Gauge[1]	Comments (problems, adjustments, observations)

[1] Note any discrepancies in space provided, or comments section.

SAMPLE

Snow Depth Gauge Calibration

Date	Time	Person	Gauge Plumb Check	Measured Gauge Height	Replace Desiccant	Gauge Zero Reading From Datalogger	Gauge Reading Box on Ground From Datalogger	Comments (problems, adjustments, observations)

Lightning Detector

Date	Time	Person	Detector Test Response	Wax Plastic Cover	Comments (problems, adjustments, observations)

CMF6, Instruments for Measuring Radiative Flux Variables

Met. Tower Site Designation ____________ ☐ Pre-Cal. ☐ Postcal. (✓)

Name__________________ Signature__________________ Calibration Date_______ Activity Log Page No. ______

Pyranometer Calibration

Serial Number	Calibration Constant (x10^{-6} V/Wm^{-2})	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	Datalogger Mult. Changed (√)	New Multiplier Value Entered in Datalogger	Comments (problems, adjustments, observations)

Pyranometer Calibration

Serial Number	Calibration Constant (x10^{-6} V/Wm^{-2})	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	Datalogger Mult. Changed (√)	New Multiplier Value Entered in Datalogger	Comments (problems, adjustments, observations)

SAMPLE

Pyrgeometer Calibration

Serial Number	Calibration Constant (x10^{-6} V/Wm^{-2})	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	Datalogger Mult. Changed (√)	New Multiplier Value Entered in Datalogger	Comments (problems, adjustments, observations)

Pyrgeometer Calibration

Serial Number	Calibration Constant (x10^{-6} V/Wm^{-2})	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	Datalogger Mult. Changed (√)	New Multiplier Value Entered in Datalogger	Comments (problems, adjustments, observations)

CMF7, Instruments for Measuring Subsurface Variables

Met. Tower Site Designation ___________ ☐ Pre-Cal. ☐ Postcal. (✓)

Name____________________ Signature______________________ Calibration Date__________ Activity Log Page No. _______

Soil Temperature Probe Calibration

Serial No.	Position/ Depth	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	Ice Bath Check Sensor / Standard	Ambient Comparison Sensor / Standard	Warm Comparison Sensor / Standard	Comments (problems, adjustments, observations)

Ground Heat Flux Plate Calibration

Serial Number	Calibration Constant ($x10^{-6}$ V/Wm^{-2})	Pre-Cal. Installation Date	Pre-Cal. Installation Time	Person	Datalogger Mult. Changed (√)	New Multiplier Value Entered in Datalogger	Comments (problems, adjustments, observations)

Soil Moisture

Model Number	Serial Number	Version Number	Pre-Calibration Installation Date	Pre-Calibration Installation Time	Operational Check Air	Operational Check Water	Person	Comments (Include installation details)

CMF8, Data Acquisition System

Met. Tower Site Designation ________________________

Name______________ Signature_______________ Activity Date______ Activity Log Page No._____

Datalogger Calibration

Serial Number	Date	Time	Person	Installed Date	Calibration (√)	Comments (problems, adjustments, observations)

Chan. No.	Sensor & Input Loc.	Mult. & Offset	Range mV	Excitation mV	Datalogger Response	Error	Excit. (0.0V)	Datalogger Response	Error
	θ_4	0.1	5000	5000			0.0		
	θ_3	"	"	"			"		
	θ_2	"	"	"			"		
	θ_1	"	"	"			"		
	U_4	0.01125	5000	5000			0.0		
	U_3	"	"	"			"		
	U_2	"	"	"			"		
	U_1	"	"	"			"		
	W_4	0.0225	5000	5000			0.0		
	W_3	"	"	"			"		
	W_2	"	"	"			"		
	W_1	"	"	"			"		
	T_4	-0.17885 & 106.06	1500	1500			0.0		
	T_3	"	"	"			"		
	T_2	"	"	"			"		
	T_1	"	"	"			"		
	T_0	"	"	"			"		
	T_S	"	"	"			"		
	K↓		50	10			0.0		
	K↑		50	10			"		
	L↓		5	1			"		
	L↑		5	1			"		
	h	0.1	5000	1000			0.0		
	p	0.1 & 600	5000	1000			0.0		

CMF9, Sodar

Name________________ Signature________________ Activity Date_______ Activity Log Page No. ____

Sodar Antenna Zenith Angle Verification (Horizontal Antennas = 20, Vertical Antenna = 0)

Antenna	NS	EW	V
Zenith Angle			

System Diagnostic Tests (Attach hard copy from TI printer) Pass ☐ Fail ☐ (√)

If any tests fail, describe the failure:

SAMPLE

System Noise Tests NS ☐ EW ☐ V ☐ (√)

Comments:

Responder Checks (Attach hard copy from TI printer)

Responder		NS Response		EW Response		V Response	
R-300							
R-600							
T-300	T-600						

uvw Tests (Attach hard copy from TI printer)

Excitation	NS Response	EW Response	V Response
+500 mV			
-500 mV			
+80 mV			
-80 mV			

uvw Tests Re-Run -- Applies Only if Sodar Adjustment Required (Attach hard copy from TI printer)

Excitation	NS Response	EW Response	V Response
+500 mV			
-500 mV			
+80 mV			
-80 mV			

Comments, Observations, Repairs (e.g., Transducer diaphragm replacements, etc.):

SAMPLE